

VIS-NIR REFLECTANCE OF WATER ICE/REGOLITH ANALOGUE MIXTURES AND IMPLICATIONS FOR THE DETECTABILITY OF ICE MIXED WITHIN PLANETARY REGOLITHS

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Water ice in polar shadowed areas of the Moon?

Use of laser altimetry and direct imaging to detect reflectance changes.

Reflectance models for mixtures.

Estimation of water ice mixed within the regolith.

Water ice in polar shadowed areas of the Moon?

Use of laser altimetry and direct imaging to detect reflectance changes.

LABORATORY MEASUREMENTS!!

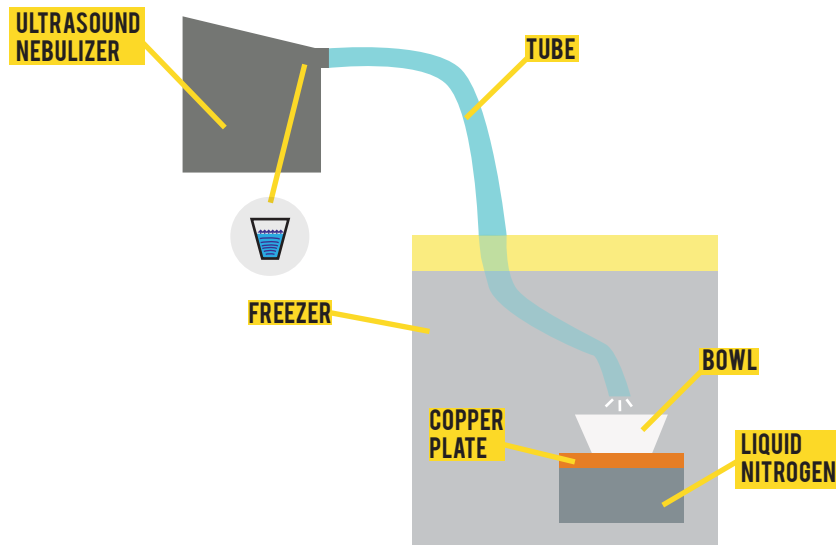
Reflectance of icy mixtures

Reflectance models for mixtures.

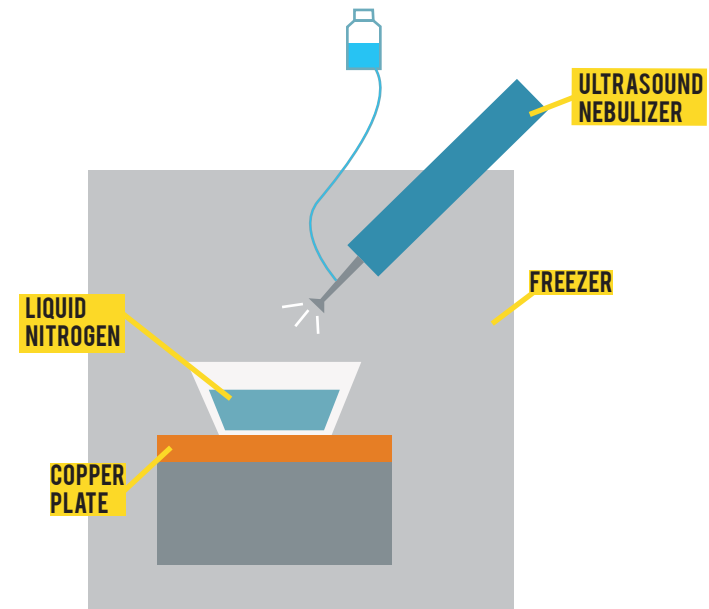
Estimation of water ice mixed within the regolith.

ICY SAMPLES

Two methods developed at the University of Bern to produce water ice



Fine-grained ice: $4.5 \pm 2.5 \mu\text{m}$



Coarse-grained ice: $70 \pm 30 \mu\text{m}$

ICY SAMPLES

We use the JSC-1 AF lunar regolith simulant.

No need of the perfect chemical / mineralogical simulant, but rather a realistic one in terms of particle size and shape.

“JSC-1 AF (“fine fraction”) has been processed [...] in order to approximate the finer component of the lunar regolith where more than 50% of the grain sizes are below 20 microns”

[Characterization Summary of JSC-1A]

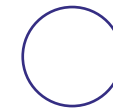
VIS-NIR REFLECTANCE OF WATER ICE/REGOLITH

ICY SAMPLES

FINE-GRAINED
ICE



COARSE-GRAINED
ICE



JSC-1 AF



Grain shape (Avg.)

Spherical, smooth

Spherical, smooth

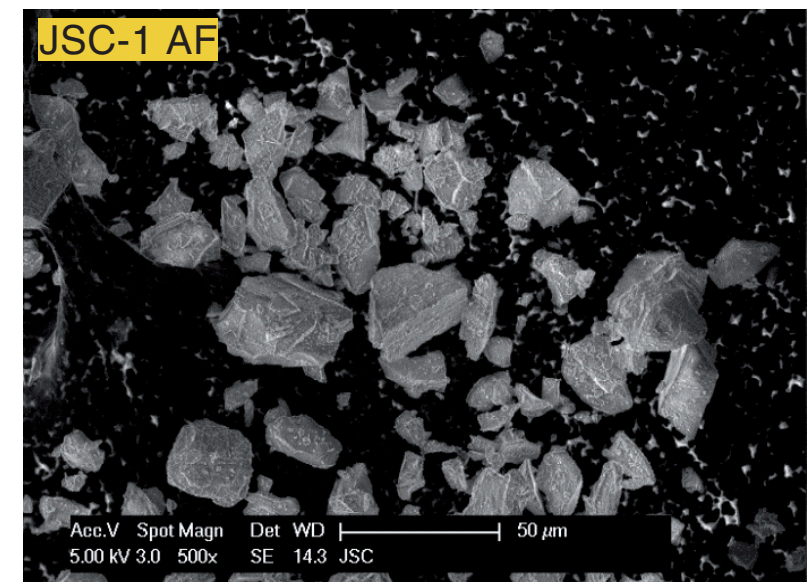
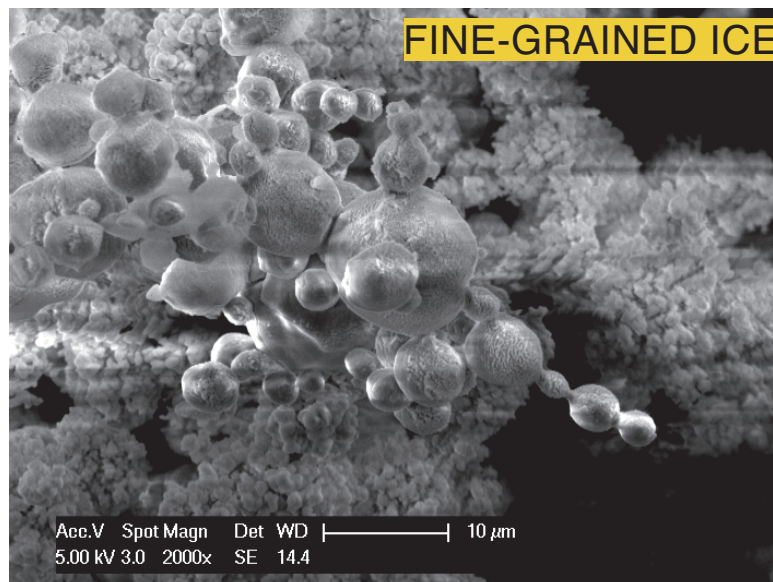
Irregular, sharp

Grain size (Avg.)

$4.5 \pm 2.5 \mu\text{m}$

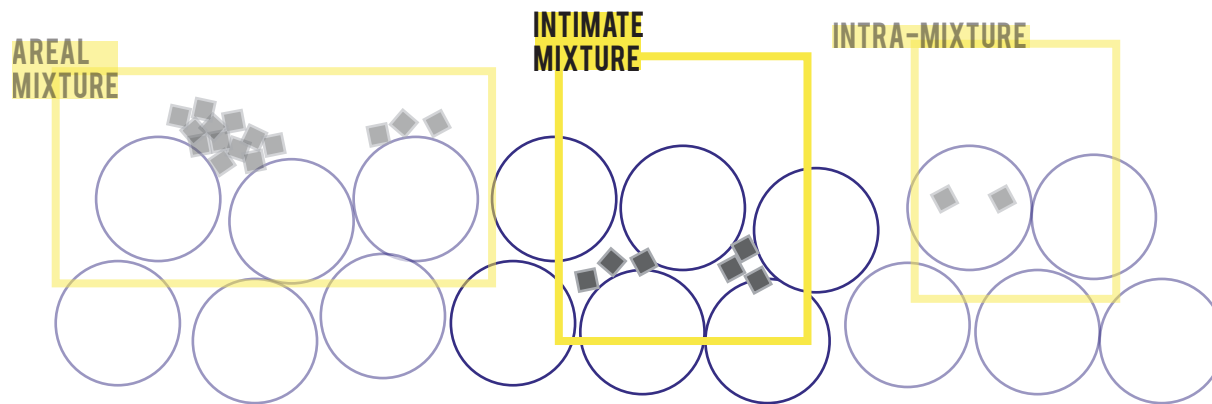
$70 \pm 30 \mu\text{m}$

$24 \mu\text{m}$ [Schrader
et al., 2009]

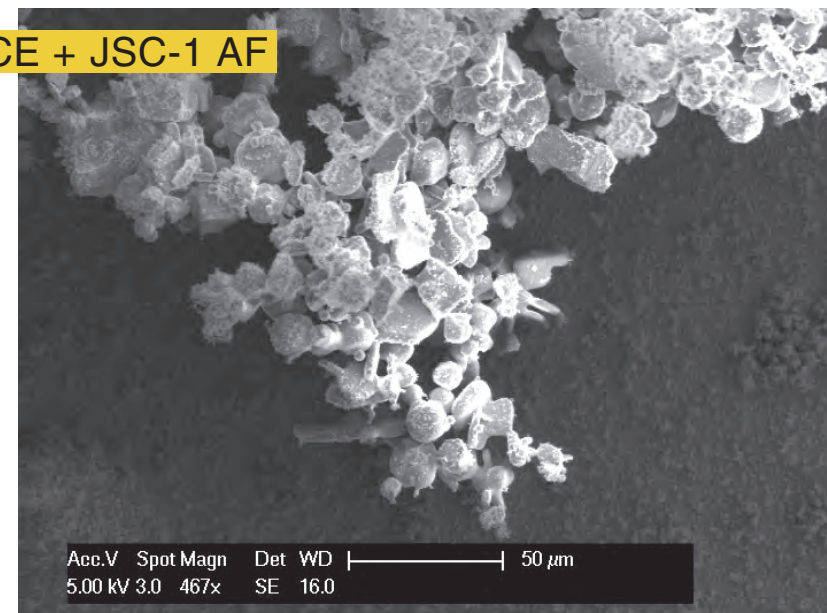
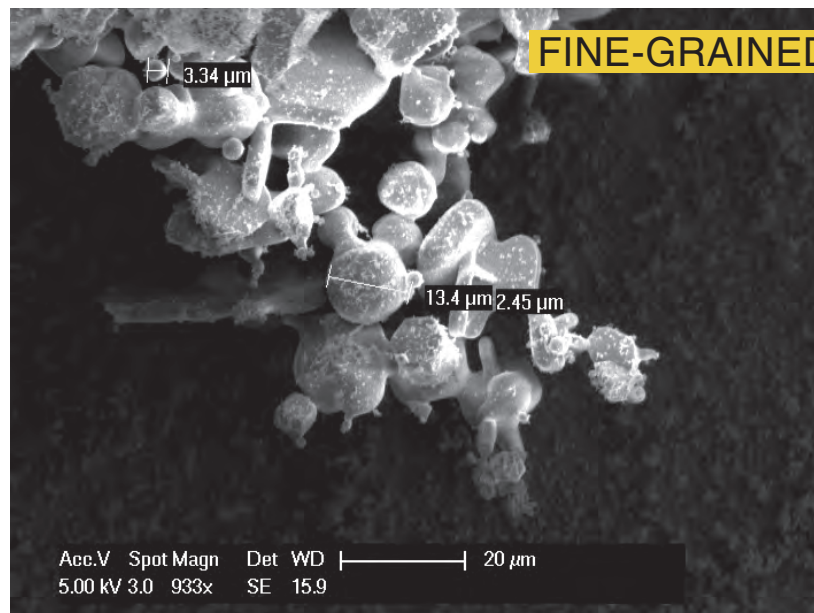


Cryo - SEM

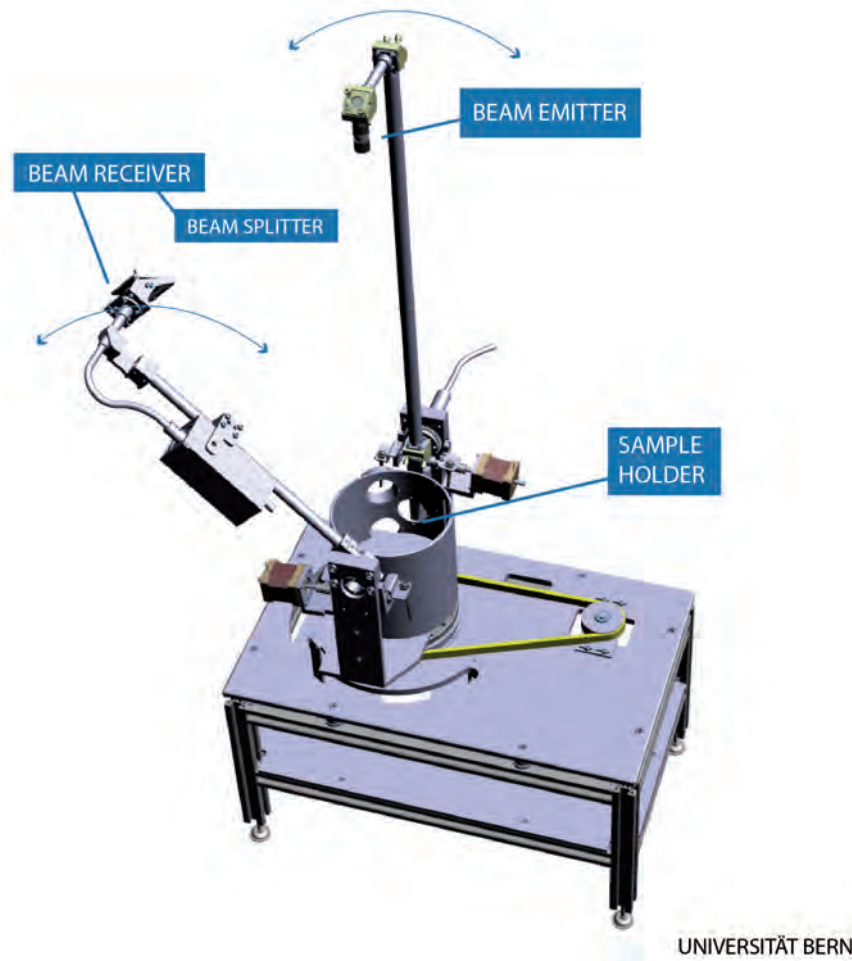
ICY SAMPLES



- » Homogeneity (shaker)
- » Cold (liquid nitrogen)
- » Tested reproducibility

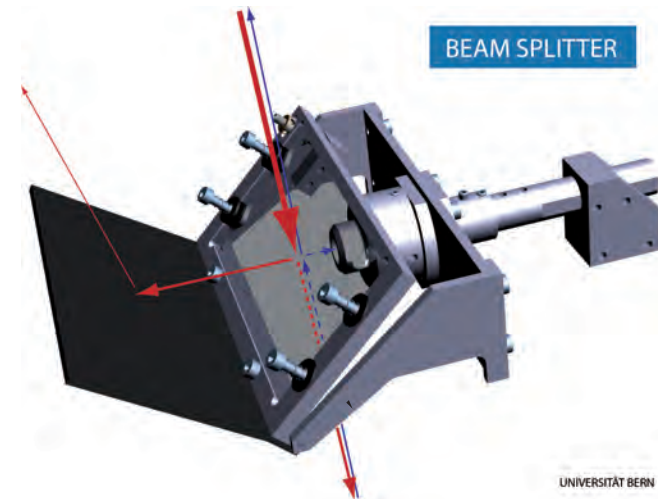


REFLECTANCE MEASUREMENTS



PHIRE-2 GONIO-RADIOMETER

Planetary Ice Laboratory.
University of Bern.



REFLECTANCE MEASUREMENTS

PHIRE-2 GONIO-RADIOMETER

- » Reflectance as a function of incidence, emission and azimuth angles; Bidirectional Reflectance Distribution Function (BRDF)
- » Measurements at low and zero phase angle.
- » VIS-NIR range (400-1100 nm). Peak SNR at 750nm.
- » From room temperature to 240K.
- » Angular resolution: $\sim 1^\circ$
- » Average relative error: $\sim 2\%$

RESULTS

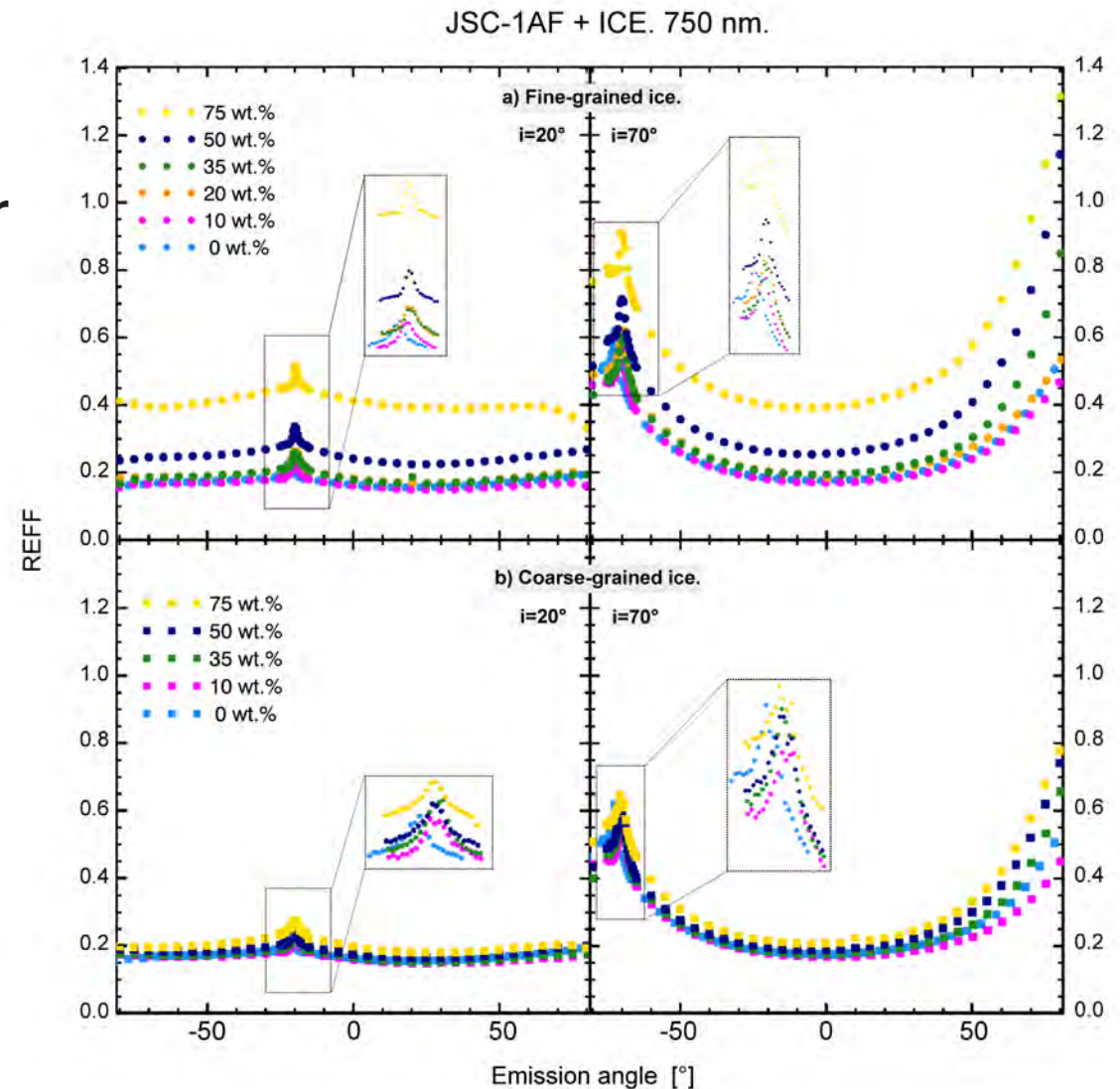
» From 0wt% to 75wt% water ice within the samples.

» $i = 20^\circ$, $i = 70^\circ$

» $\lambda = 750\text{nm}$

» $T = 240\text{K}$.

No significant photometric signature of water ice



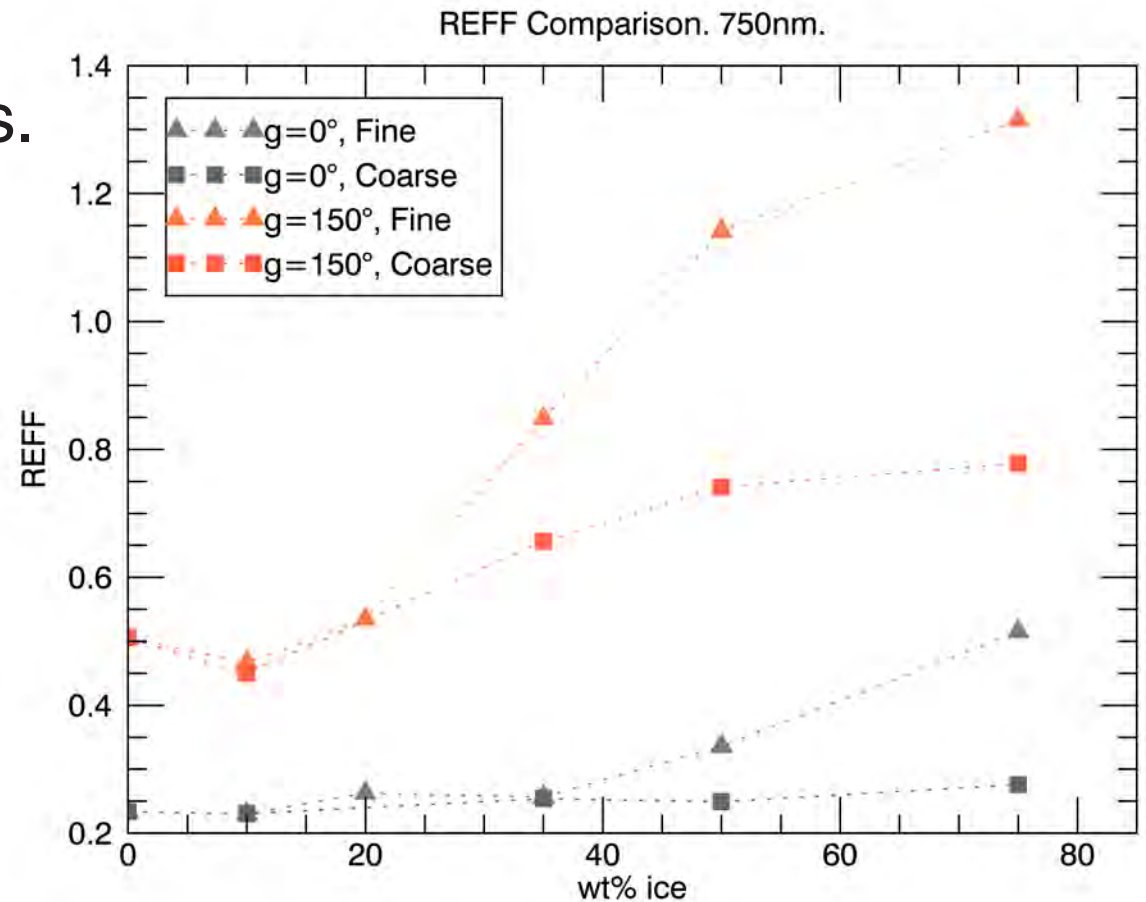
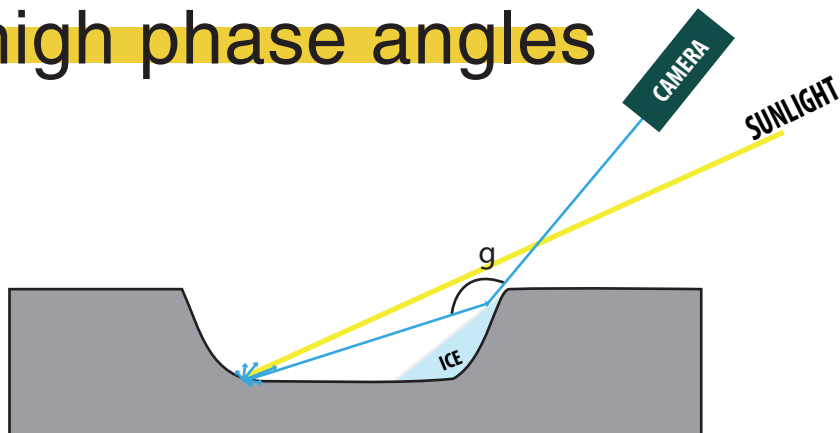
RESULTS

» Low Vs High Phase angles.

» $g = 0^\circ$, $i = 20^\circ$

» $g = 150^\circ$, $i = 70^\circ$

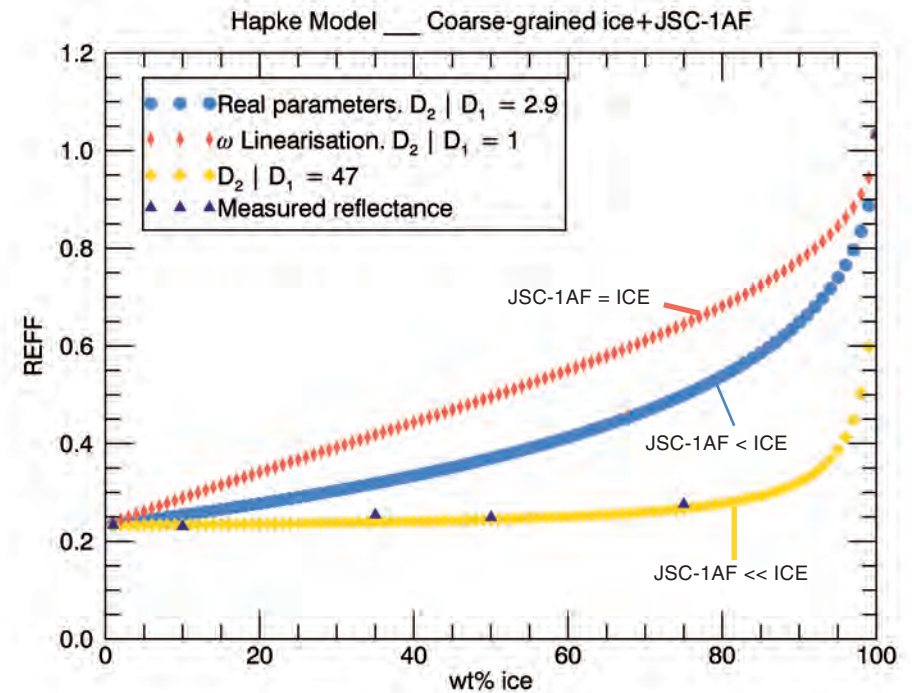
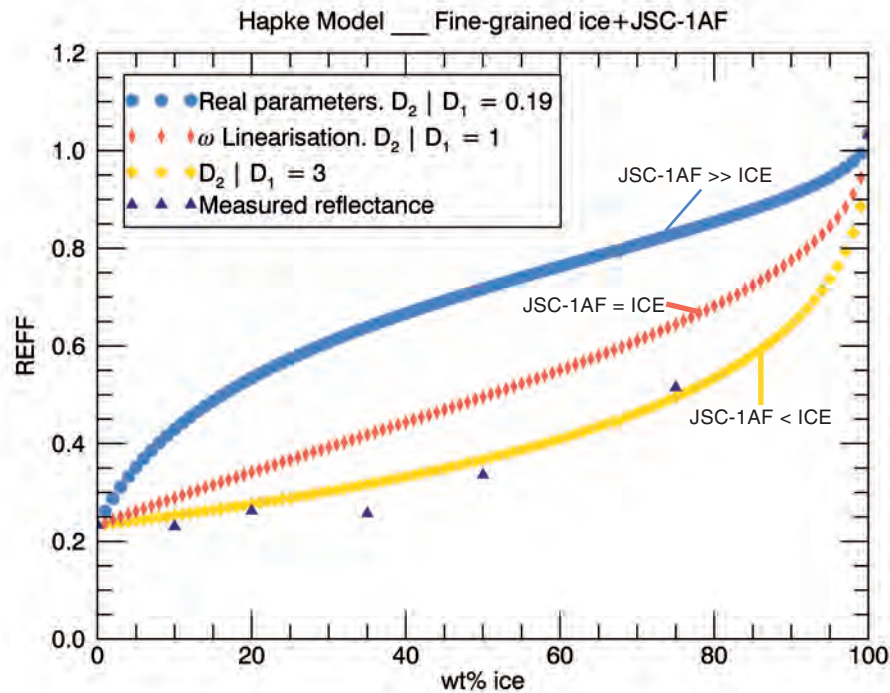
Ice revealed sooner at
high phase angles



ANALYSIS – THE HAPKE MODEL

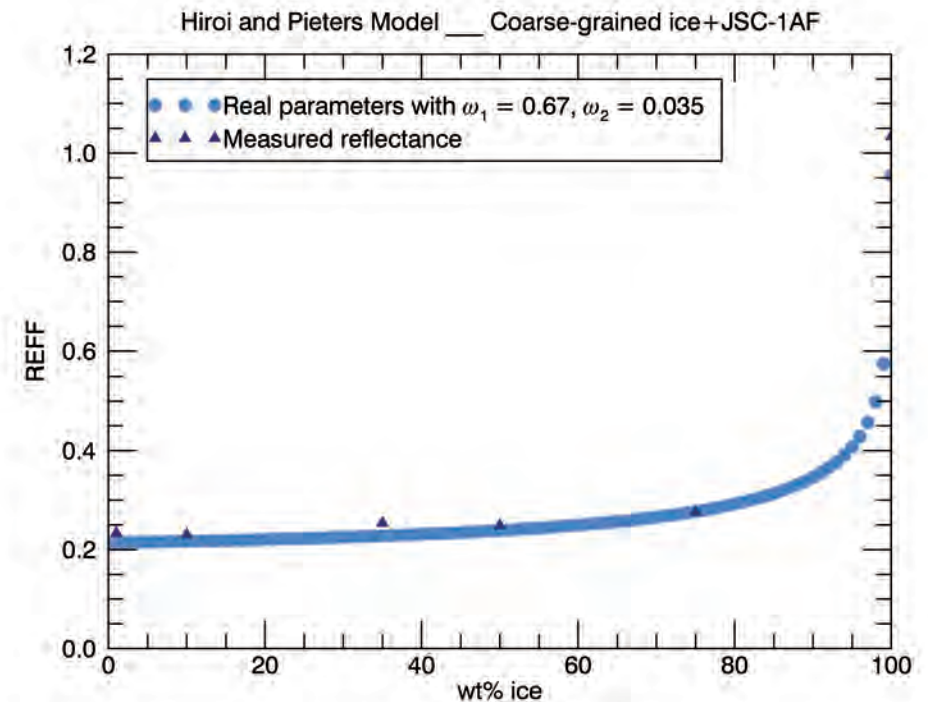
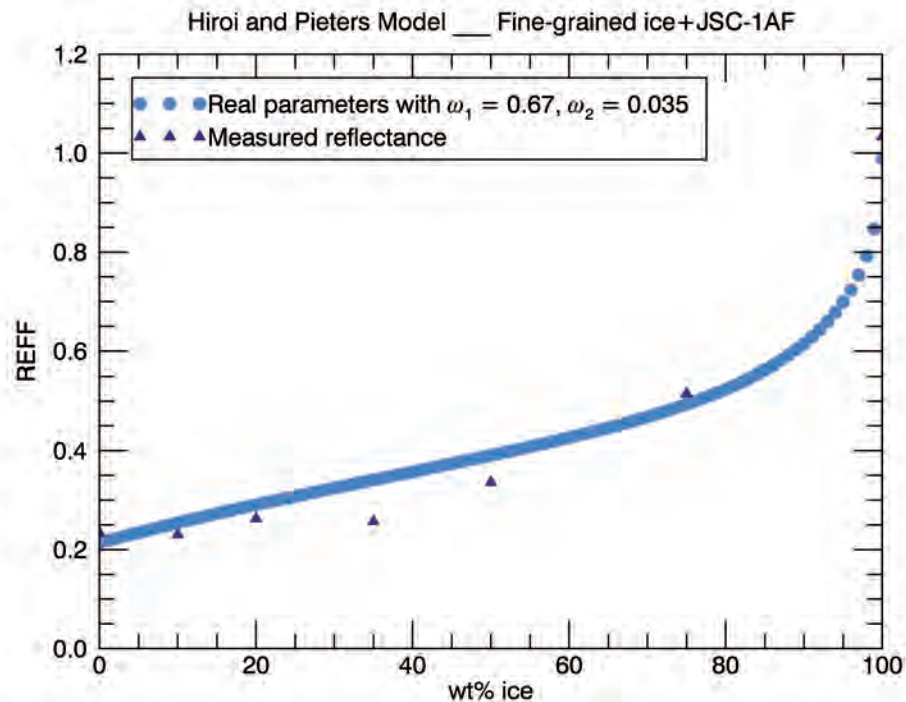
$$\omega = \frac{\zeta \omega_1 + \omega_2}{1 + \zeta}, \quad \zeta = \frac{M_1}{M_2} \frac{\rho_2}{\rho_1} \frac{D_2}{D_1} \xrightarrow{D_2 = D_1} \omega = [\text{wt}\% \cdot \omega]_{\text{ice}} + [\text{wt}\% \cdot \omega]_{\text{regolith}}$$

[Hapke, 1993]



ANALYSIS – THE HIROI MODEL

- » Effective scatterer size [\neq particle size!] [Hiroi and Takeda, 1990]
- » Free parameters ω_1, ω_2



CONCLUSIONS

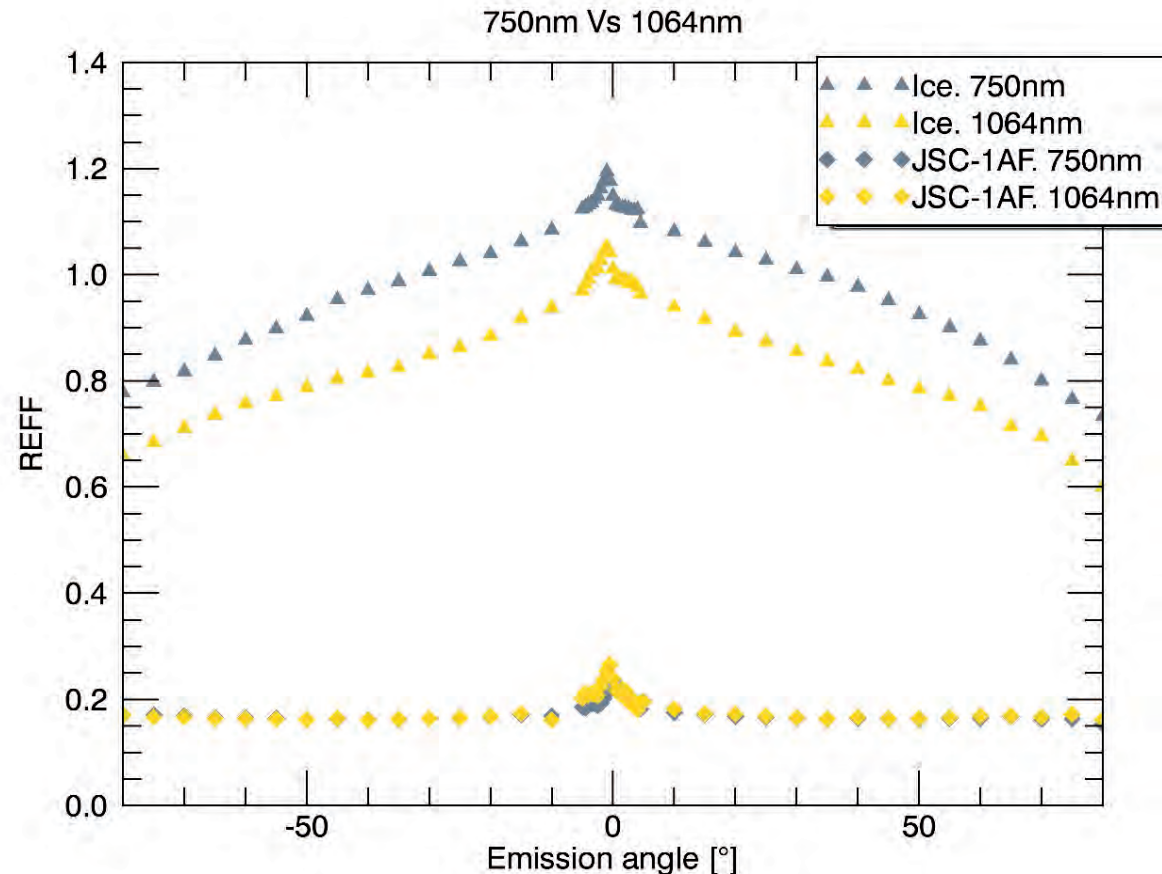
- » No VIS significant photometric signature of water ice.
- » Big particulate ice harder to detect.
- » High phase angle more effective to detect ice.
- » Models work well in a relative way; shape and size cannot be neglected.
- » Water ice estimate to be taken with caution!
- » Implications for Mercury.

MORE IN: YOLDI ET AL., 2015. GEOPH. RES. LETTERS

THANK YOU!

MORE IN: [YOLDI ET AL., 2015. GEOPH. RES. LETTERS](#)

1064NM Vs 750NM



“the fine particles can have an effect [on the reflectance] all out of proportion to their mass fraction”.

[Hapke, 1993]

VIS-NIR REFLECTANCE OF WATER ICE/REGOLITH

$i = 0^\circ, i = 20^\circ$

